everests of waste

A distillation of India's waste landscape

Imperatives and market opportunities: 2025

If India was to load all their waste into garbage trucks, 40 million garbage trucks, lined up bumper-to-bumper, would circle the Earth three times.

executive summary

India's waste economy is now central to both its climate and livelihood realities. The country generates over 62 Mt of municipal solid waste every year and an additional 350–400 Mt of industrial, construction, and agricultural waste, but less than 45% is scientifically processed or recycled. The rest is openly dumped or burned, releasing an estimated 36–40 $MtCO_2e$ annually from landfills and 180 $MtCO_2e$ from open-field residue burning. Methane emissions from unmanaged organic waste—28 times more potent than CO_2—exacerbate local heat, smog, and flooding, while uncollected waste clogs drains and increases flood losses now estimated at ₹100,000 crore per year.

In comparison to global benchmarks, India generates less waste than global averages, and significantly less than developed countries - an average of about 0.7 kgs per capita in India compared to 1.4 kg per capita in Europe. Even in comparison to relatively peer countries such as Kenya, Indonesia and Brazil, India generates less waste. India's collection is also relatively strong on paper (~95%), but effective processing lags advanced benchmarks: India processes close to 50% of collected waste vs EU's 48% recycling/composting of all municipal waste. India is still ahead of peer countries in terms of waste processing, and therefore holds significant potential for designing testing innovations at scale for the Global South, and becoming a global forerunner in the circular economy.

Waste Stream	India's Current Status	Comparable Developing Peers	Potential if Circularity Scales
Agro & Crop Residue	Less than 30% is reused, generating around 180 Mt of CO_2e emissions every year	Brazil recovers 55% of its waste, and China has more than 80% recovery	Investments in bioenergy and large scale composting could create 5 million rural jobs, cut ₹1 lakh crore in losses
Municipal Solid Waste	Only about 35–40% is processed	Globally, we are closer to Indonesia at 30% than to Brazil at 60%	2 million jobs could be unlocked; 27 $MtCO_2e$ reduced; unlocking a value of ₹ 1 lakh cr
Plastic Waste	Only 13% recycled	China recycles only 15%, but South Africa recycles 43%	1 million jobs unlocked and ₹20,000 crore in material value recovered
Textile Waste	<1% is recycled	Bangladesh, another textile hub recycles about 5%, while China has achieved 20%	₹25–30,000 crore value unlocked
C&D Waste	<15 % recycled	Brazil recycles 50%, South Africa 35%	Recycled aggregates could result in ₹50,000 crore savings and the creation of semi-skilled jobs
E-Waste	<15% is formally processed	China processed 30%, and Brazil 17%	₹50,000 crore in metals could be recovered; high-skill recycling jobs could lay a pathway for more dignified and safer labour
Hazardous & Industrial	~50 % tracked	Brazil is at 60%, while China is miles ahead at 90%	Primary gains here are efficiency gains, less toxicity in surrounding areas, and improved health outcomes

The waste economy also sustains 6–7 million workers, including 1.75 million informal waste pickers, 5 million sanitation workers, and small recyclers, transporters, and micro-entrepreneurs. Over 60% are women, many working without safety gear, insurance, or predictable incomes. Waste pickers and recyclers face exposure to heat, toxins, and floods, while rural SHGs managing compost or biogas units struggle with erratic feedstock supply and minimal financial returns. For communities near dumps, air and water pollution translate directly into chronic health costs and lost workdays.

This report shows that India's waste stream recovery and circularity are behind global leaders, but broadly within or ahead of many developing country peers for certain streams (e.g., plastic recycling is at about 13% vs a developing country average of 10-15%). Still, for many streams (agri-residue, MSW, C&D, e-waste) the gap is large, ensuring major potential for innovation, jobs and investment.

India therefore sits at an early-to-mid stage of circular transition. The next decade offers the chance to close this 40-point circularity gap through technology, formalisation, and investment alignment that can jointly reduce emissions and expand livelihoods. The sector's unrealised value is immense—up to ₹900 billion and 5–7 million green jobs by 2040. Proven technologies already exist: AI-enabled segregation, IoT-based fleet tracking, decentralised bio-CNG clusters, automated sorting for C&D waste, and digital traceability systems that integrate informal workers into formal chains. Verified emission data, digital worker IDs, and climate finance tied to methane reduction can rewire India's waste economy into a transparent, investable system.

India's waste sector is no longer a peripheral urban service—it is a high-emission, high-employment system that can anchor the country's just transition. A unified, technology-enabled circularity mission can transform waste from a climate liability into one of India's most accessible, low-carbon livelihood engines.

The/Nudge Institute & the^delta Prize are committed to helping India solve for challenges that the bottom 30% of the population face, and doing so at scale. the^delta Prize does so through it's Grand Challenge model, the first of its kind in India, by:

- Guiding markets to solve for the underserved by using competition to direct talent and capital into areas typically neglected by private investment
- Providing catalytic inducements aligned with seed-to-series funding needs of innovators, ensuring ideas are not only socially impactful but investable and scalable
- Mobilising ecosystems—corporates, government, academia, and funders—to create systemic momentum and long-term adoption of proven solutions
- Generating credible evidence through rigorous M&E processes (baseline, midline, endline) that validate both impact and investability

Prize prioritises technology-led breakthroughs that achieve time-bound, quantifiable impact, can unlock 10–30× downstream capital multipliers, and will lead to sustained market or policy adoption.

At the^delta prize, our focus doesn't stop at understanding complex problems and systems, but goes further to induce market models & tech-first solutions that could unlock these complex systems. Through evidence, incentives, and ecosystem orchestration, each challenge hopes to transform a complex social issue into an investable innovation frontier.

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1
introduction

It is a truth (now) universally acknowledged, that climate change impacts poorer populations disproportionately. Their health and living environments are severely impacted, while their already precarious livelihoods are thrown into further instability - causing in turn, a deeper slide into vulnerability. These effects can't be fixed overnight as the problems themselves are global in nature, even when the impact is most felt by a farmer on their one acre of land.

While scientific and policy communities look to tackle climate change at a global scale, this report explores where markets can play a role in mitigating the impacts of climate change, and simultaneously supporting vulnerable populations in climate-proofing their livelihoods. Markets are able to mobilise resources and achieve results (albeit short term) on a faster timeline than policy is able to, and therefore plays a critical role in how we can work to sustain communities until larger term systemic change kicks into effect. We explore where the ecosystem can induce innovation and competition to rapidly solve some of India's most pressing climatic concerns, and provide the bottom 30% with the agency to shore up their defenses against climate change.

1.1 wherein lies the problem?

India, the world's most populous country, is at extreme risk of climate change and its impacts. In India, climate change and global warming is associated with extreme weather events and their impacts,[1] with a majority of Indians expressing concern about the impact of global warming and extreme weather events.[2] At a geographic level, 57% of Indian districts, home to 76% of the country's population, are at high to very high risk from extreme heat.[3] The World Bank estimates that up to 75% of India's workforce depends on heat-exposed labour, which in turn contributes to approximately 50% of the GDP.[4] SELCO, in a 2023 study, found that extreme weather events most affect livelihoods by reducing productivity, a loss of assets (livestock and agricultural produce), and early retirement for health reasons - all compounding to lesser income, and for fewer productive working years.[5]

1.2 approach

the^delta prize undertook a study on climate and livelihoods for the bottom 30% of India's population. The study delved into the impact of climate on manufacturing, waste, food, hospitality and care, transportation, and informal livelihoods.

The sectors which show the most promise for circular economy strategies to reduce emissions are buildings and other construction, transport and the food system, where they can reduce emissions from production, use (in terms of energy used for heating, cooling and fuelling) and disposal (when they are sent to the incinerator or the landfill). Instead of recycling at the end of materials' life cycle, upstream strategies that include shifting consumption patterns and designing products that use materials more efficiently have the highest potential to reduce emissions.

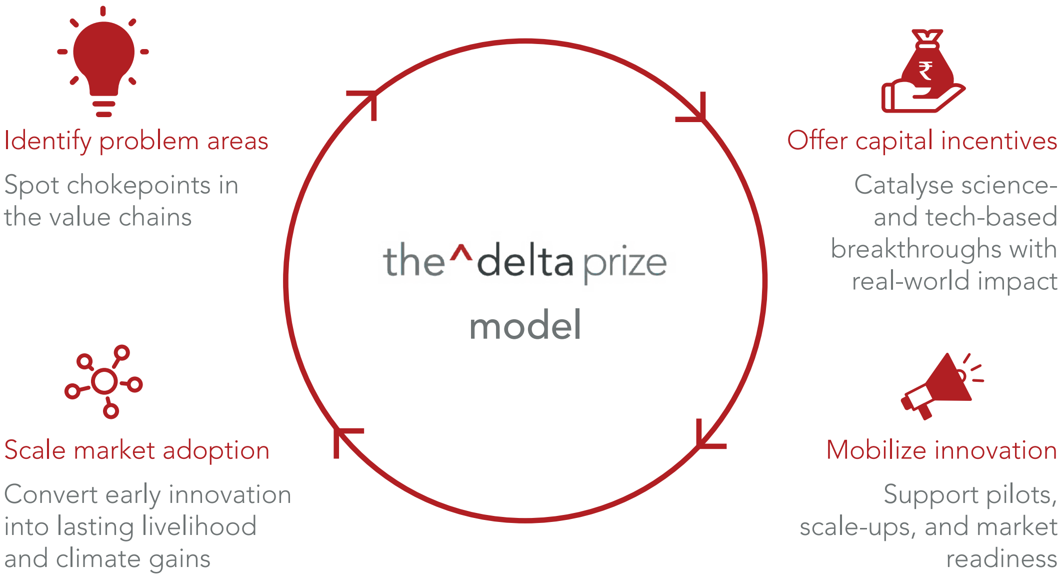
A detailed analysis of the impact of climate on each sector was undertaken, with an eye on where markets could be prompted to play a role, and work with individuals affected by adverse climatic conditions to secure their livelihoods. Industries like mining and manufacturing have significant impacts on people's livelihoods, exacerbated by climate change, but these require systemic overhaul at an industry scale with significant policy oversight. Miners have very little control over any aspect of their employment, and markets can play little role in mitigating the impacts of climate change, or bolstering their income.

Sectors such as food systems and waste management however, due to the fragmented nature of these systems, show greater promise for market based interventions. This report presents a cumulative view of value chains in the waste sector, to highlight the economic losses and opportunities in these chains, with an eye on enhancing livelihoods for the bottom 30% and contributing to net economic growth.

1.3 incentive based plays

At the^delta, Prize runs an incentive-based grand challenge model to drive innovations at scale and improve livelihoods for the bottom 30%. We identify technological choke points that are holding back scale and adoption across different waste value streams. the^delta prize guides markets to solve for the underserved through grand innovation challenges. We offer incentives that meet the seed / series capital aspirations of the brightest problem solvers, demonstrate investability, and mobilize sustained attention and momentum for specific problem areas through our interventions. To that end, this report identifies problem areas with great potential for effective market interventions, and lays the groundwork for more targeted interventions where we see opportunity for science based tech enabled solutions that improve livelihoods and support in climate proofing our economy.

How Incentive-Based Innovation Unlocks Climate-Resilient Livelihoods



Innovation at scale

- Tackles market inefficiencies
- Accelerates breakthrough solutions for vulnerable communities

Tech-based solutions

- Drives sustainable tech uptake
- Improves adaptive tech uptake

Livelihood resilience

- Supports bottom 30%
- Strengthens income stability

> **Incentives can turn climate challenges into innovation opportunities -driving scalable, market-ready solutions for India's most vulnerable.**

2
everests of (untapped) waste

India generates an estimated 350–400 Mt of industrial, construction, agricultural, and hazardous waste (CPCB 2022; NITI Aayog 2023) and over 62 Mt of municipal solid waste (MSW) annually. Only ~45 % of this waste is scientifically processed or recycled. The remainder either decomposes in open dumpsites, is burnt, or leaks into water and soil systems—representing both a material loss and a public-health risk.

This is a problem that is being severely exacerbated by climate change and climate stressors, such as extreme weather events, and increased risk of disease.

> By 2040, all of Delhi will be a landfill.

If current trends persist, by 2040 India could face:

Waste generation doubling to
~700 Mt annually

Landfill land demand exceeding
1,400 sq km, roughly the size of Delhi

Economic losses of
₹ 2–3 lakh crore per year
through uncollected material value, remediation costs, and health expenditures[6]

Yet, a coordinated circular-economy transition could unlock:

₹ 4–5 lakh crore
in recoverable material and energy value

5–10 million new green and grey-collar jobs
across collection, sorting, repair, remanufacturing, and recycling;

300 Mt
CO_2-equivalent annual emissions reduction potential

Improved social protection
and digital inclusion for millions of informal workers.

To that end, this report identifies investable waste-stream opportunities across rural and urban waste. Rural waste is dominated by agricultural waste, with smaller quantities of other waste value chains. Urban waste comprises of municipal solid, plastics, construction and demolition (C&D), e-waste, textiles, hazardous, and organics. The report covers: scale of the problem, demographics affected, economic and climatic implications of inaction. Specifically, the report calls for investment in science backed tech enabled innovative technologies that will enable solving for India's (untapped) waste problem, and result in downstream benefits to waste pickers and sanitation workers through expansion of value streams and improved working conditions.

Climate Stressor	Urban	Rural	Livelihoods Impacted
Heatwaves & Rising Temperatures 	During extreme heat, landfills frequently catch fire, releasing toxic smoke into nearby communities. High temperatures also accelerate the decomposition of organic and agricultural waste, producing strong odours and breeding vectors. Collection vehicles risk overheating and require additional cooling, while workers face greater exposure to flies, which breed faster in warm temperatures and transmit infectious diseases. Waste workers face unsafe working conditions as prolonged exposure to heat worsens fatigue and respiratory risks.	In rural areas, high temperatures cause crop residues to decompose rapidly, reducing their usefulness as fodder or compost. Composting and biogas operations are disrupted due to water scarcity, and prolonged heat leads to food spoilage, creating waste and income losses.	**Urban** Waste pickers, sanitation workers, municipal staff, SHGs managing compost **Rural** Farmers handling residues, rural composting SHGs
Flooding & Extreme Rainfall 	Intense rainfall and flooding often clog urban drains with plastic and other waste, leading to severe waterlogging. Processing facilities face the need for enclosed or covered sorting to manage waterlogged waste. Disposal sites experience increased flooding, leachate, and runoff, requiring more collection and treatment	Heavy rainfall and floods frequently wash away agricultural residues and recyclables stored outdoors, reducing both income and usable material for rural collectors and farmers.	**Urban** Sanitation workers, waste pickers, urban slum dwellers **Rural** Small kabaris, farmers losing agri residues, rural recyclers
Droughts & Erratic Rainfall 	Low or erratic rainfall disrupts composting and biogas operations in urban areas that depend on water. Absence of adequate cold chains during prolonged heat causes perishable food to spoil, creating waste and financial losses.	Insufficient rainfall reduces the availability and demand for crop residues as animal fodder or biomass. Small and marginal farmers face reduced income from agricultural waste, while rural SHGs and biomass collectors struggle to maintain operations.	**Urban** SHGs in composting, mandi workers **Rural** Small & marginal farmers, rural biomass collectors
Smog & Air Pollution Episodes 		Farmers burning crop residues contribute to local air pollution, which affects the health of communities and livestock in rural areas.	**Urban** Waste pickers, urban poor near landfills, transport/ logistics workers **Rural** Farmers burning residues

Table: Impact of climate stressors on waste streams

Climate Stressor	Urban	Rural	Livelihoods Impacted
Vector-Borne Disease Rise (linked to climate + waste)	Flooding combined with stagnant waste in urban areas creates breeding grounds for mosquitoes and other disease vectors. Unmanaged organic waste spreads pathogens rapidly, increasing the risk of diseases such as dengue, malaria, and diarrheal infections.	Unmanaged organic waste provides breeding grounds for vectors and spreads pathogens, increasing the prevalence of vector-borne and waste-related diseases in local communities.	**Urban** Sanitation workers, waste pickers, informal settlement residents **Rural** Women SHGs managing wet waste, rural communities near open dumping sites
Heat + Toxic Exposure in Informal Recycling	Informal e-waste and plastic recycling in urban areas becomes more dangerous during high temperatures, as heat intensifies the release of toxic fumes from burning wires, plastics, and acids. Workers often operate without ventilation or protective equipment.	Backyard plastic and e-waste recycling exposes women and youth to extreme heat and toxic fumes, creating significant health risks.	**Urban** Informal e-waste dismantlers, kabaris, small-scale recyclers **Rural** Women/youth in backyard workshops, rural recyclers

Table: Impact of climate stressors on waste streams

2.1 India's waste workforce and livelihood overview

India's waste economy is sustained by an extensive, mostly invisible workforce of nearly 6–7 million people. These workers form the base of India's waste economy - Informal pickers for instance, recover an estimated 15–20% of all recyclable materials from MSW streams, saving municipalities around ₹300–400 crore annually in avoided collection costs.[1] Furthermore, 85% of India's farmers are smallholder farmers and they generate significant agro-waste and crop residue. Due to the decentralised nature of waste generation, these workers and farmers remain indispensable to the waste value chain and will do so regardless of upstream innovations and advancements. Technological advancements often marginalise, and even exclude, those employed at the bottom of the value chain. It is imperative in the case of waste and a transition to a circular economy, that tech enabled innovations incorporate and include those at the frontline, and solutions are rooted in understanding the dynamics of livelihoods associated with the value chain.

Category	Estimated Workforce (2023)	Gender Share	Key Roles
Sanitation workers (contracted by urban local bodies)	5 million	70% men	Collection, sweeping, drain cleaning[7]
Informal waste pickers	1.75 million	60% women	Segregation, resale, sorting[8]
Scrap dealers and small recyclers	200,000+	80% men	Aggregation, resale[9]
Formal private-sector waste employees	300,000	25% women	Transport, processing, management[10]

Table: Waste Workers in India

Livelihoods in the waste sector cover multiple trades - informal and formal, and across value chains. We also know that:

- 80% live below the poverty line; 60% are women
- Over 90% of manual scavengers and waste handlers belong to Scheduled Castes[11]
- Women pickers face dual marginalization—low wages (₹150–250/day) and exposure to health hazards in landfills and other waste sites with minimal occupational protections where their work is typically relegated to
- Limited access to healthcare, insurance, or protective equipment[12] - 150 deaths recorded in 2022-2023 due to hazardous cleaning
- Studies by IIT-Bombay and AIIMS show 20–25% prevalence of respiratory and dermatological disorders among waste pickers; life expectancy is 10 years shorter than national average
- Roughly 15% of informal recyclers are under 14 years old in metro landfill areas[13]

2.1.1 economic and livelihood potential in waste

There is significant opportunity to enhance livelihoods - both income, and occupational safety - for those employed in the informal waste sector. A long term plan for improving livelihoods focuses on the formalisation of those in the sector, where the value could reach close to ₹900 billion.

> **If even 50% of India's waste workforce were formalized and equipped with mechanised tools, the sector could create 5–7 million sustainable jobs by 2040.**

₹17,000 crore
Informal sector's annual recycling value[14]

15-20%
Share of total waste recovery (by weight)[15]

₹80,000 crore
Potential value by 2040 (with formalisation)[17]

₹1,500 crore from plastics
₹800 crore from metals
₹600 crore from paper[16]
Value of material recovered (2024)

Economic potential of the informal waste sector

Type of waste	Rural / Urban	Problem Areas	Livelihoods Associated	Technology Needs for Livelihood Workers
Agricultural & Agro-industrial Waste (crop residues, bagasse, food processing waste)	Rural	Crop residues are often burnt, contributing to air pollution and climate change. Rising heat accelerates decomposition, making residues less useful. Farmers lack affordable collection and processing infrastructure, leaving them without viable alternatives. Prolonged droughts and erratic rainfall further reduce demand for residues as fodder.	Small & marginal farmers, agricultural labourers, rural biomass collectors.	Low-cost, portable residue collection and baling machines; mobile bio-digesters and small-scale composters; digital platforms that link farmers to biomass buyers; affordable protective gear for handling biomass; Tools for high-value processing: small-scale bio-refineries for enzymes, biochar kilns, fiber composite presses (e.g., pineapple fiber), vermicomposting kits, and bio-packaging systems (e.g., Agringenium).
Organic Waste (food loss & waste) (farm-gate, mandis, households)	Both	Heatwaves and lack of cold chains cause spoilage at farm-gate, eroding farmer incomes; urban organic waste ends up in landfills, generating methane that worsens heat stress for nearby residents; mandis lack composting or digestion facilities, exposing workers to rotting waste and foul air.	Farmers, mandi workers, small traders, food vendors, waste pickers.	Solar-powered cold storage units for farms/mandis; portable biogas digesters; composting machines at community/market level; mobile apps for food redistribution; digitised scheduling and tracking tools for collection and composting.
Municipal Solid Waste (MSW) (organic, plastics, paper, textiles)	Urban	Poor segregation reduces recyclability, forcing reliance on landfills; methane emissions, landfill fires, and waste flooding pose direct health risks for nearby communities; workers in waste management are exposed to unsafe, unhygienic conditions and climate extremes (working outdoors in heatwaves and floods).	Informal waste pickers, municipal sanitation workers, low-income communities near dumps.	AI- or sensor-based segregation tools at collection points; mobile apps for waste pickers to connect directly to recyclers/ULBs; ergonomic pushcarts and protective equipment; real-time traceability platforms and worker ID systems (as modeled by Saahas) to ensure transparency, payments, and inclusion.
Plastics & Packaging Waste (single-use, multilayered plastics)	Urban & Peri-Urban	Multilayered plastics persist in the environment; microplastics contaminate soil and water, entering the food chain; informal recyclers only recover high-value plastics, leaving the rest unmanaged; climate extremes like flooding spread plastic debris into rivers and agricultural fields, impacting food and water security.	Informal recyclers, kabadiwalas, small retailers, plastic factory workers.	Low-cost shredders and densifiers for low-value plastics; chemical recycling access points; traceability apps to aggregate plastics for bulk sale; safer sorting equipment (gloves, masks, fume extraction); digital compliance platforms linked to EPR systems to help informal recyclers participate in formal value chains.
Construction & Demolition (C&D) Waste (concrete, sand, steel, debris)	Urban / Semi-Urban	Informal dumping of debris worsens flooding and pollutes air; extreme heat increases dust hazards for nearby residents and workers; secondary markets for recycled aggregates are weak, limiting recycling efforts; migrant demolition workers often lack safety gear and face high exposure to accidents.	Migrant demolition workers, small contractors, informal recyclers, urban poor near dumps.	Affordable crushing and sorting machines for small contractors; safer demolition tools; digital marketplaces and platforms connecting informal recyclers to secondary material markets.

Table: Waste streams and associated livelihoods needs

Type of waste	Rural / Urban	Problem Areas	Livelihoods Associated	Technology Needs for Livelihood Workers
E-Waste (electronics, batteries, solar PV panels)	Urban & Peri-Urban	Over 90% of e-waste is handled by the informal sector using unsafe methods like open burning and acid leaching; heatwaves and rains worsen contamination risks for workers; lack of advanced facilities limits recovery of valuable rare earths; workers, often women and children, face toxic exposure daily, with no access to healthcare or protective gear.	Informal dismantlers, kabadiwalas, small refurbishers, scrap dealers.	Safe dismantling kits (non-burning tools); training in certified practices; collection kiosks linked to formal recyclers; wearable protection (gloves, goggles, masks); digital compliance tools and traceable handover systems to formalize earnings and recycling outcomes.
Sanitary & Menstrual Waste	Rural & Urban	Sanitary and diaper waste is often unsegregated and unmanaged, creating both health and dignity challenges; in some panchayats, up to 200 kg/day of menstrual waste accumulates without safe treatment; climate heat worsens odours and leachate, increasing risks for waste workers.	Women in households and SHGs; waste workers (often women) handling mixed streams without protection.	Safe collection and treatment systems; menstrual cup/pad distribution platforms; awareness and behavior-change campaigns; protective handling gear.

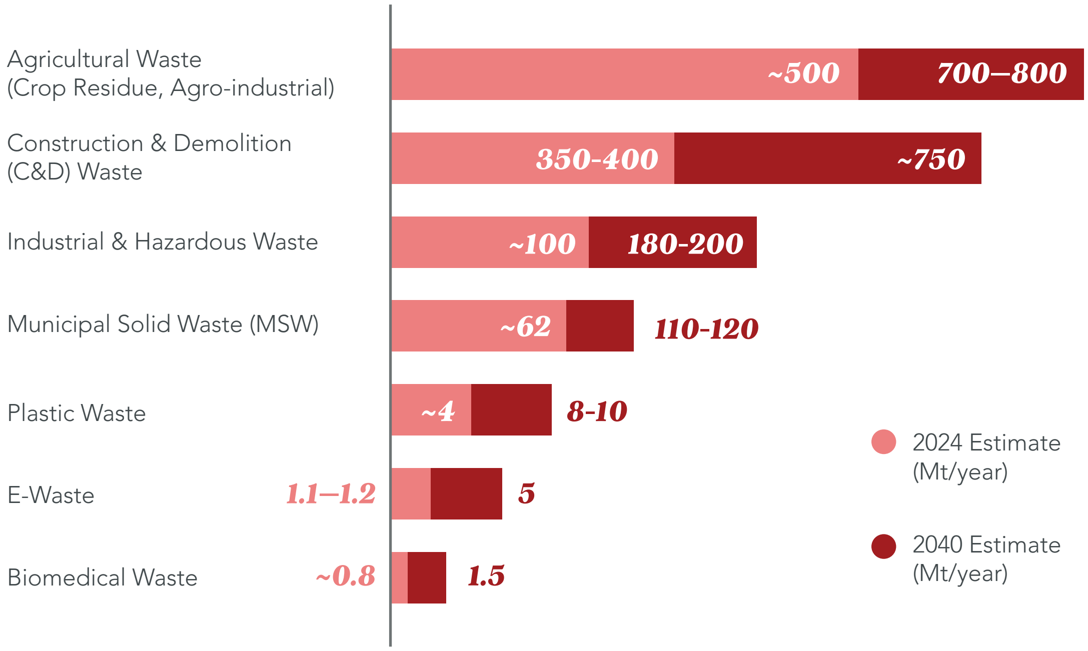
Table: Waste streams and associated livelihoods needs

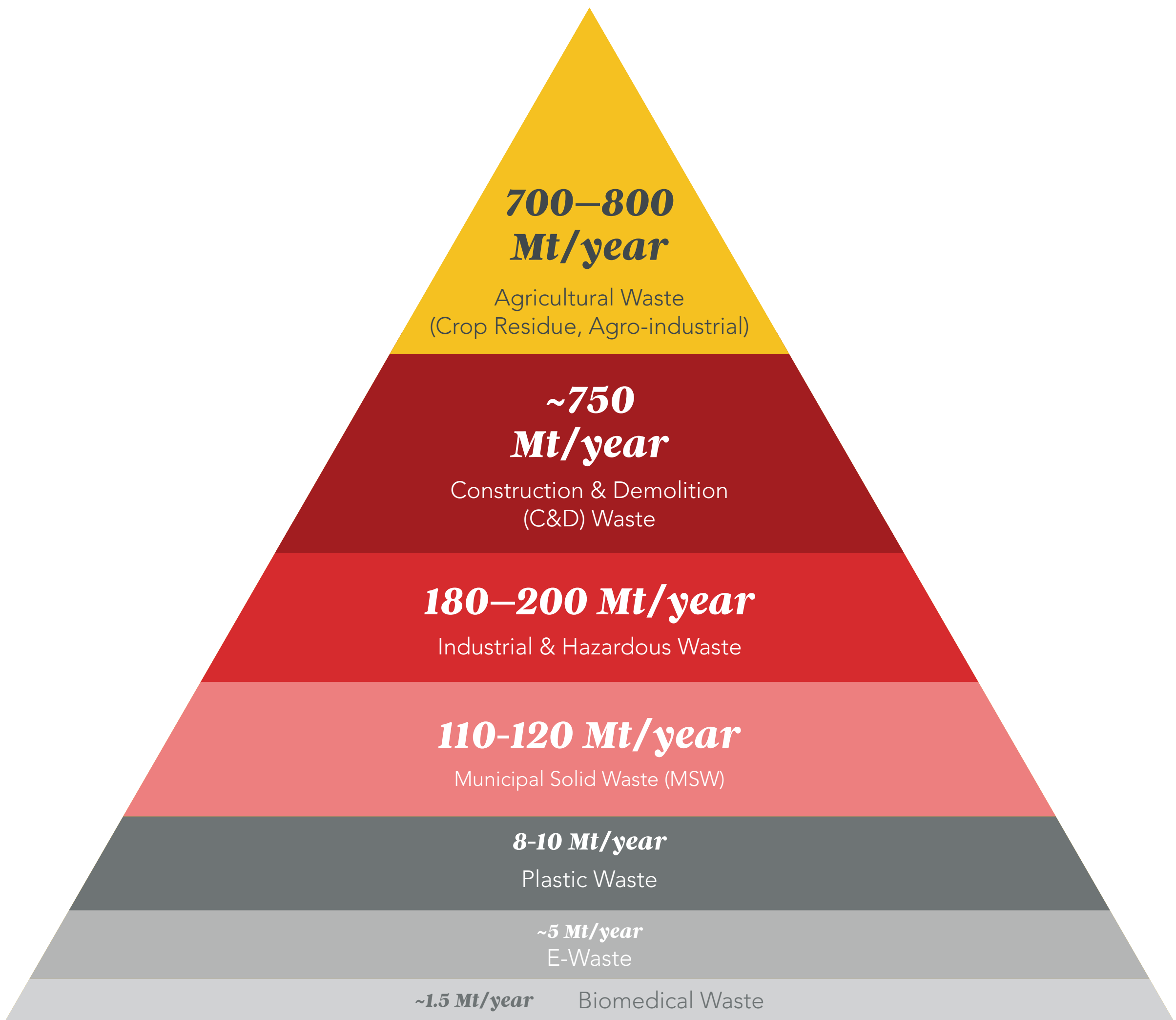
However, key barriers to their large-scale exclusion include fragmented regulation - such as state-level inconsistencies in waste worker recognition; and technological exclusion - digital literacy and smartphone access remain low. While there exist some national level efforts to support waste workers - the Swachh Bharat Mission' Urban 2.0 and National Policy on Resource Efficiency (2023) aim to integrate informal workers into circular supply chains - implementation remains slow with less than 15% of ULBs designing official waste-picker inclusion mechanisms. Studies indicate an average income of ₹5000/month and poor work conditions, with limited scope for mobility. Farmers and their interaction with agro-waste is not even considered when discussing the waste economy in India. While policy and legal battles are underway to protect waste pickers and promote their rights, these take significantly long to come into effect. Market opportunities to improve their income in the immediate term would yield crucial benefits to workers.

> **The quickest pathways to unlock additional income sources for frontline waste workers lie in two areas: improved efficiency and/or opening up new value chains.**

The livelihoods of India's poorest communities are intertwined with waste. Any technological or financial innovation in the sector must embed inclusive business models—cooperative material recovery facilities, digitally enabled trading platforms, or micro-franchise models—to ensure social equity alongside circularity. This report reframes waste as an untapped resource thus highlighting their economic potential in multiple value chains, while also showing us how to move forward keeping in mind climate and social justice goals.

India's waste landscape: 2024–2040





India's waste landscape 2040 projection

3 rural waste

3.1 agricultural & agro-residue waste

India generates about 600 Mt of agwaste every year, and over 1 billion tonne of livestock waste. About 50% of crop residue is surplus and isn't used for fuel, fodder, or soil. 65% of this is burned (close to 100 Mt). Innovations in utilising this waste could significantly help in diversifying farmer income, improving bio inputs for agriculture thus reducing cost to the farmer, and solving for significant climate issues.

3.1.1 scale of the problem

India produces between 600 Mt of crop residues and agro-processing waste per year, of which 30–40% is burned, releasing more than 180 Mt of pollutants and CO_2e annually.[18]

Waste Component	2024 Estimate (Mt)	2040 Projection (Mt)
Total crop residue generated[19]	600	750
Residue burned (open-field)[20]	190	160 (declining trend)
Emissions from burning[21]	180	120 (if controlled)
Bioenergy potential[22]	230	350
Compostable potential[23]	150	180

Table: Agro waste estimates

Waste Component	Problem Areas	Technology Needs for Livelihood Workers
Agricultural & Agro-industrial Waste (crop residues, bagasse, food processing waste)	Crop residues are often burnt, contributing to air pollution and climate change. Rising heat accelerates decomposition, making residues less useful. Farmers lack affordable collection and processing infrastructure, leaving them without viable alternatives. Prolonged droughts and erratic rainfall further reduce demand for residues as fodder.	Low-cost, portable residue collection and baling machines; mobile bio-digesters and small-scale composters; digital platforms that link farmers to biomass buyers; affordable protective gear for handling biomass; Tools for high-value processing: small-scale bio-refineries for enzymes, biochar kilns, fiber composite presses (e.g., pineapple fiber), vermicomposting kits, and bio-packaging systems (e.g., Agringenium)

Table: Technological needs to promote livelihoods

3.1.2 the human cost

- Smallholder farmers (owning <2 ha) make up 85% of India's farming population and are most affected by residue management costs[24]
- Landless labourers rely on residue for fodder or fuel; burning deprives them of this resource
- Women contribute heavily to post-harvest residue management—manual collection, sorting, composting—yet receive minimal income
- In Punjab and Haryana for instance, crop residue burning contributes up to 45% of seasonal PM2.5[25], disproportionately impacting poor rural households

3.1.3 financial and climatic cost of inaction and action

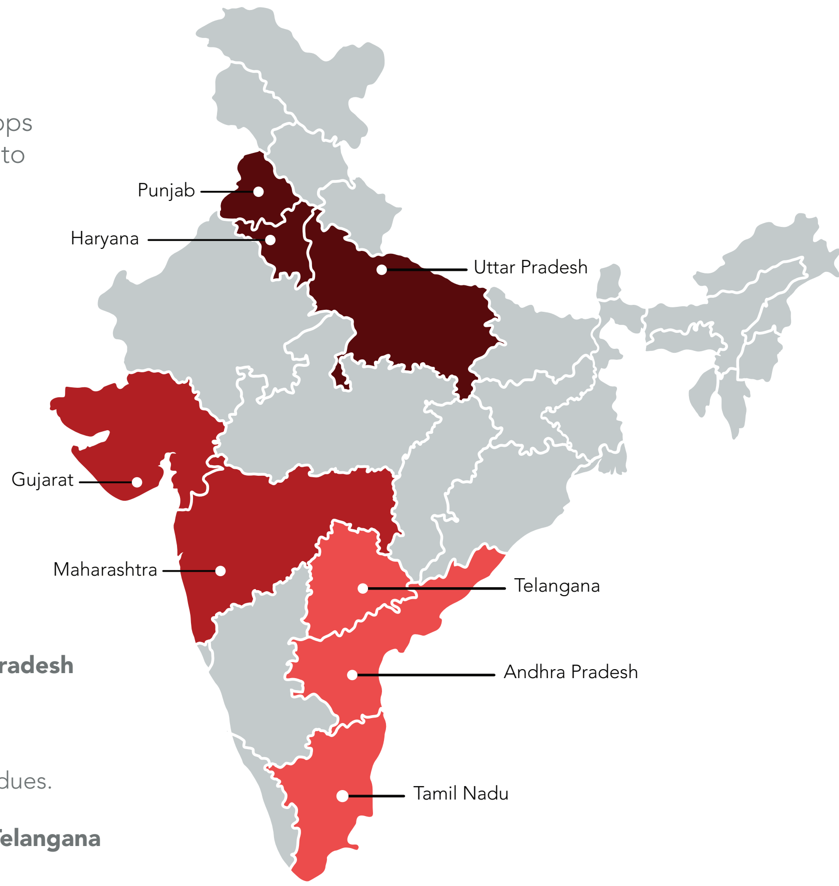
> **The financial and climatic cost of the status quo could cost ₹5000 crore per year in direct economic losses by 2040.**

It is estimated that health (respiratory and cardiac)[26] costs could approach ₹50,000 crore, value of lost soil nutrients could amount to ₹13,000 crore,[27] missed bioenergy value[28] of ₹27,500 crore, and air quality GDP loss of ₹80,000 crore.[29]

> **India loses 1.36% of its GDP because of air pollution alone every year. Just the health costs are more than the GDP of 40 countries.**

3.1.4 regional hotspots

India's agro-waste problem is also concentrated in certain regions and crops within, which could serve as a pathway to innovate, experiment, and scale if structured such.



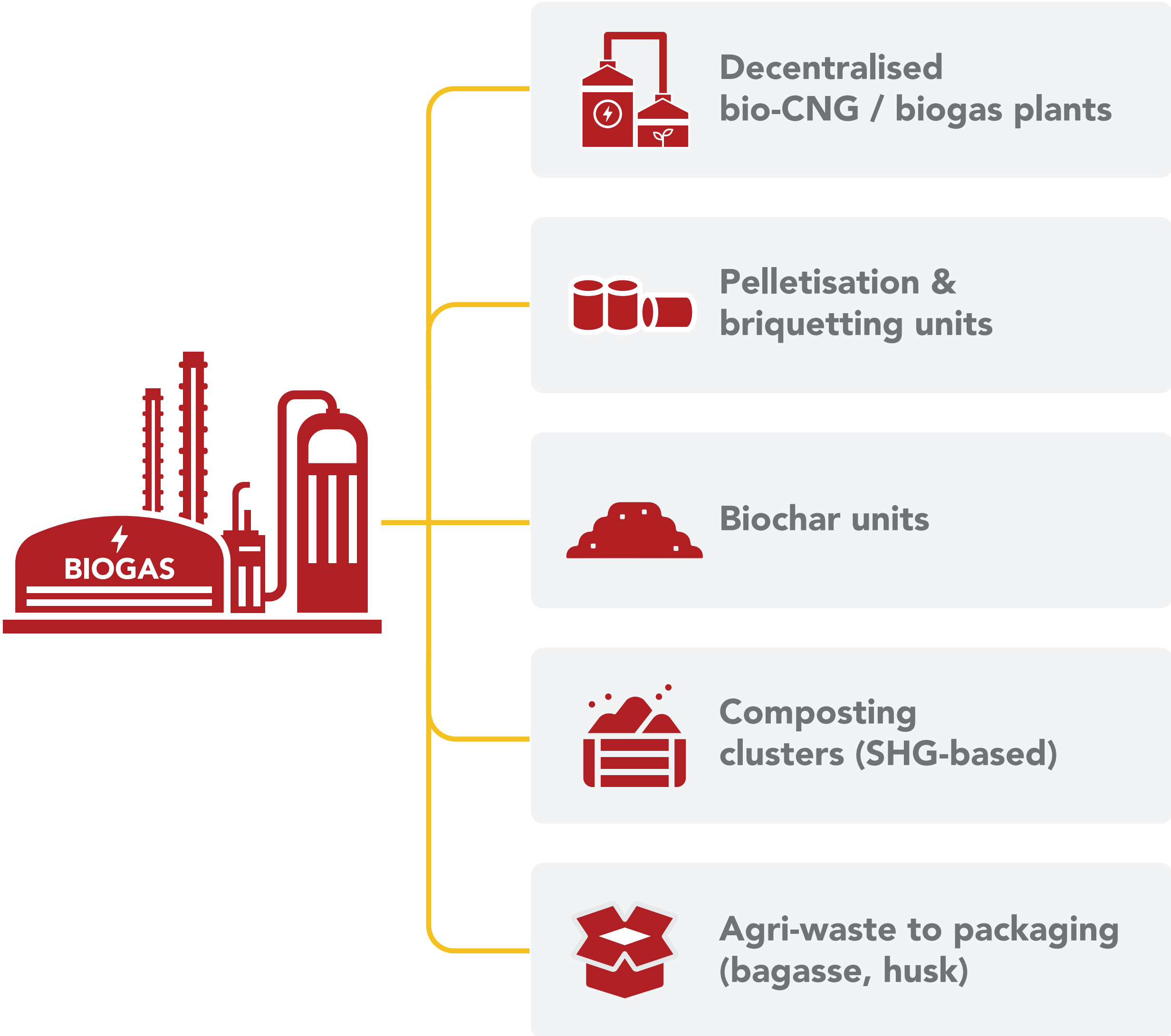
North India: Punjab, Haryana, Uttar Pradesh
rice straw burning remains endemic.

West: Maharashtra and Gujarat
sugarcane bagasse and cotton stalk residues.

South: Tamil Nadu, Andhra Pradesh, Telangana
paddy husk and coconut waste.

current innovations with scalable potential

- Decentralised bio-CNG / biogas plants: Convert crop residues and manure into transport-grade fuel and liquid digestate, displacing diesel/LPG and returning nutrients to soils; works best in cluster models with assured offtake
- Pelletisation & briquetting units: Densify loose biomass into reliable industrial fuel, enabling coal substitution for small kilns/boilers and creating rural MSME value chains
- Biochar units: Produce stable carbon for soils while locking emissions; improves soil organic carbon and moisture retention with potential carbon-credit revenue for smallholders
- Composting clusters (SHG-based): Market/GP-level hubs that turn organics into saleable compost, creating steady SHG incomes and reducing methane from open dumping
- Agri-waste to packaging (bagasse, husk): Moulded fibre and biocomposites that replace single-use plastics and wood; scalable with quality standards and long-term procurement contracts



3.1.5 case study: bioenergy from paddy straw, Punjab

VERBIO has built a commercial-scale straw-to-biomethane (bio-CNG) biorefinery in Punjab that converts paddy straw into automotive-grade biomethane and biofertiliser, thus preventing residue burning. It is the first, largest, and only plant of its kind in India and Asia. The refinery aims to tackle paddy-stubble burning while creating a substitute for diesel and piped CNG for vehicles. While an expensive intervention (capital expenditure could run into the multi-crore rupees), the refinery creates farm level demand for straw as feedstock, and brings in jobs to rural areas, as an alternative to farming. Adaptation pathways to scale would consist of clustering aggregation hubs, testing a scaled down version of the refinery, securing demand for bio-CNG, and then replicating this hub and cluster model at scale. Government enabled financing through SATAT, Ethanol financing, and CBG incentives could be utilised for adaptations and pilots, while also tapping into newer and emerging pools of carbon financing.

Inputs

33 TPD Bio-CNG

100,000 t/year paddy straw

₹2 billion

Outcome

- 45,000 tonnes CO_2 avoided annually
- local farmers paid ₹1,500–1,700/ tonne straw

Impact

- 370 rural jobs created (40% women)
- Replicable model under SATAT
- 10 more projects in pipeline

> **Agricultural waste management offers the largest immediate opportunity for rural job creation and GHG mitigation. Decentralised, tech-enabled bioenergy and composting can deliver socioeconomic and climate dividends simultaneously.**

Livelihood Opportunity	Ease of Adoption	Climate Impact Potential	Who Can Benefit Most	Why This Matters
Composting & Vermicomposting Units	low-tech; SHGs/youth can adopt quickly	Cuts methane; improves soil health	Women SHGs; rural youth; landless labour	Simple tech, steady market for compost, strong co-benefits for local soil and nutrition.
Biochar Micro-enterprises	needs small kilns, some training	GHG mitigation + soil resilience + carbon credits	Small farmers; youth entrepreneurs	Creates a new income stream from carbon markets; enhances soil moisture retention under climate stress.
Biogas / Bio-CNG Micro-plants	moderate tech and infra needs	Clean energy, replaces firewood/coal, reduces methane	Rural entrepreneurs; small transport operators	Meets local energy needs; reduces indoor air pollution; supports clean cooking transitions.
Mushroom Cultivation on Agri Residues	low-tech; SHGs already scaling	Income diversification, limited emission gains	Women SHGs; youth; small farmers	Strong nutrition and income gains; women/youth-friendly; quick turnaround.
Briquette & Pellet Making Units	Needs machines and aggregation	Replaces coal/wood in rural industry and households	Biomass aggregators; rural MSMEs	Creates rural industry jobs; builds circular energy markets.
Agro-residue Packaging (plates, containers, cutlery)	Moderate machinery, molds needed	Replaces plastics; reduces land/water pollution	SHGs; MSMEs; youth entrepreneurs	Taps into EPR-driven demand for alternatives to plastic; can link to urban green markets.
Animal Feed Production from Residues	medium tech; existing demand	reduces open dumping, supports circular farming	Farmers; feed entrepreneurs	Reliable demand from poultry/dairy; strong rural linkage; prevents waste spoilage.
Fiber Extraction & Biocomposites (e.g., pineapple, banana, jute husk)	requires specialized machinery and markets	Bio-based materials replacing plastics/wood	Skilled rural youth; MSMEs	High value-addition, but harder for small players without support; potential for export.
Small-scale Bio-refineries (enzymes, nutraceuticals, oils)	High-tech; requires labs, investment	Circular economy; displaces fossil-based chemicals	Startups; biotech graduates	Long-term innovation space; not immediately accessible to marginal workers.

Table: Market opportunities in the agro-waste sector

3.1.6 the^delta take and ecosystem implications

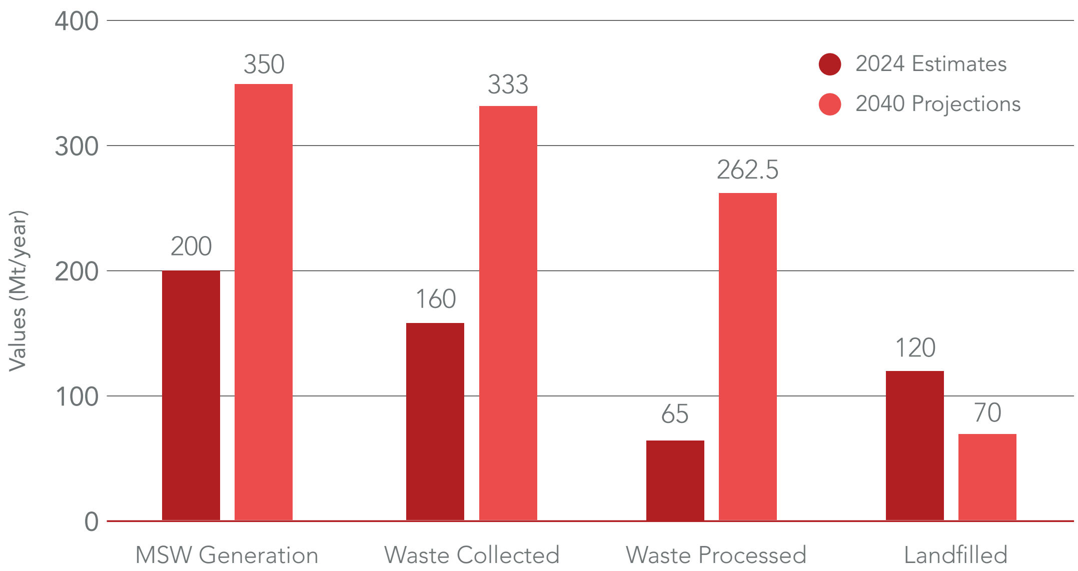
Agricultural and agro-residue waste now sits at the core of India's rural climate and livelihood equation. The country produces over 600 Mt of crop residues annually, of which roughly one-third—around 180–200 Mt—is burned, releasing 180 $MtCO_2e$ and eroding soil nutrients worth ₹13,000 crore each year. The losses ripple through the rural economy: smallholders lose potential feedstock value; landless workers lose access to fodder and fuel; and women engaged in post-harvest residue management remain unpaid for high-labour, low-return tasks. Health impacts are equally severe—smog from stubble burning contributes up to 45% of seasonal PM2.5 in North India, adding to ₹50,000 crore in annual treatment costs and productivity loss.

The opportunity, however, is equally large. The bioenergy potential of agro-waste exceeds 230 Mt annually, enough to power a circular rural industry if supported by accessible technology and financing. Low-cost baling machines, mobile digesters, biochar kilns, and digital biomass marketplaces can transform residues from pollutants into feedstock for compost, energy, packaging, and fibre composites. Cluster-level aggregation, verified carbon accounting, and decentralised bio-CNG or composting hubs can integrate smallholders and SHGs into these value chains. Harnessed systematically, agri-waste management can become one of rural India's fastest-growing livelihood sectors—linking emissions reduction, soil regeneration, and income diversification through technology and data-led circular models.

4
urban and peri-urban waste

4.1 municipal solid waste (MSW)

Municipal solid waste may be the type of waste the readers of this report are most familiar with. India's cities generate approximately 200 Mt of municipal solid waste each year, projected to rise to 350 Mt by 2040 (CPCB, 2023; NITI Aayog, 2024). Within this, organic (biodegradable) waste forms 48–55 % of MSW, translating to 80 Mt annually (CPCB, 2024). Of this further, 180 Mt is collected. Of the collected waste, only 54% is treated, 24% deposited in landfills, and the remaining 22% goes unaccounted for due to leakages in the waste supply chain. Therefore, only 30-35% of this is and will be processed, if current trends persist. Due to this, health and environmental losses exceed ₹20,000 crore annually. Rapid urbanisation, changing consumption patterns, and population growth (expected to reach 1.6 billion by 2040) are the primary drivers. Specifically, unsegregated waste remains a major barrier: only 60% of households practice source segregation, despite Swachh Bharat mandates. Most of it remains untreated—either landfilled or openly dumped—creating methane emissions and groundwater contamination (World Bank, 2023).



200 Mt
of Municipal Solid Waste

350 Mt
is projected by 2040

A breakdown of MSW

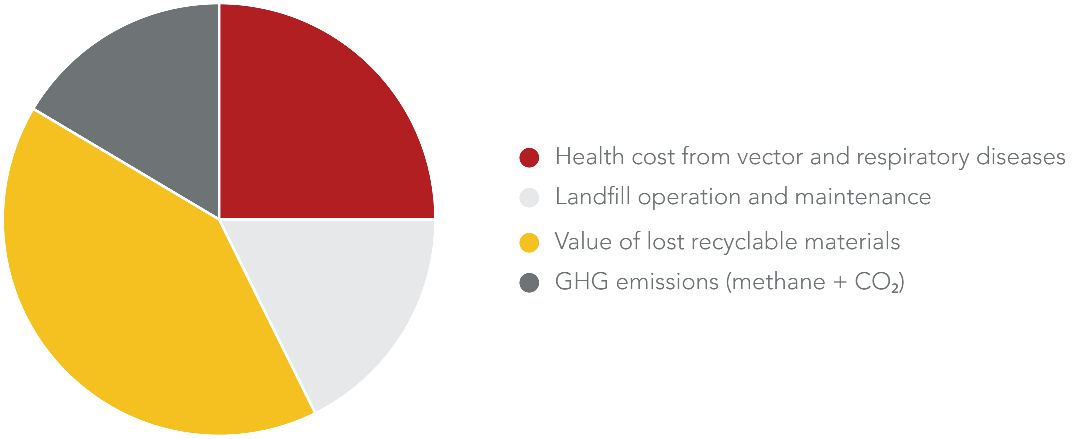
4.1.1 the human cost

A very broad range of actors are in or parallel to the MSW value chain. Farmers must process post-harvest losses, market vendors, hotel/restaurant workers, municipal waste handlers, are at the frontlines of waste generation with little occupational protection. Informal waste collectors face the brunt of the negative externalities related to waste. Waste pickers collect, sort, and sell high value waste to Material Recovery Facilities (MRFs). Waste items with market value such as metals, PET, paper, glass find markets, while the rest is left in landfills. Waste picker incomes are therefore dependent on the products they can recover, sort, and sell. However, despite being at the frontline of climate work, climate change also makes waste picking harder and more dangerous. Recent heat waves across India have hit waste pickers especially hard. A 2024 AP report describes young children and elders scavenging in 43°C heat at a Jammu landfill.[31] Experts warn that outdoor workers like waste pickers are among "the most vulnerable and highly exposed to heat." Many pickers collapse or become ill during brutal summers; one report notes that some now cut back to one meal a day to afford hospital visits when they fall sick. Furthermore, they live in and near landfills and their families fall victim to disease borne vectors, compounding health costs.

4.1.2 economic and climatic cost of inaction

Sheerly from a climatic perspective, without intervention, MSW could contribute nearly 10% of India's total methane emissions by 2040.

Cost Type	Annual Estimate (2024)
Health cost from vector and respiratory diseases[32]	₹10,000 crore
Landfill operation and maintenance[33]	₹80,000 crore
Value of lost recyclable materials[34]	₹15,000 crore
GHG emissions (methane + CO_2)[35]	60 Mt CO_2-eq/yr



Annual Cost Estimates for 2024

4.1.3 tech and investment opportunities

Increasing the uptake of waste and incorporating them into supply chains is the most critical step in reducing methane emissions, increasing livelihood opportunities for waste pickers, and bolstering India's economic growth journey.

Key innovations in the area include:

- Hasiru Dala's initiative titled 'Hasiru Batte' (Green Cloth) to find alternatives to discarded textiles
- Without recycles "unrecyclable" waste (MLPs) like chips packets into high-quality materials and products e.g. sunglasses
- Community composting & decentralised anaerobic digesters for neighbourhoods, markets and institutions
- Bio-CNG clusters for larger organic flows (markets, wholesale mandi waste)
- Innovations like SAAnA reactor (BITS Pilani) and mobile biodigesters exist in pilot form

However, market barriers are feedstock segregation, operator skills, and market offtake for digestate/compost. Skill trainings for waste pickers and other frontline sanitation workers will be critical for successful uptake of any initiative.

4.1.4 waste picker cooperatives

A key social advancement in this sector is the successful establishment of waste picker cooperatives which straddle debates around formalisation, privatisation, and unionisation of waste pickers. Cooperatives and trade unions such as Pune's SWaCH cooperative and Ambikapur's SAMCLAF, have emerged as semi-formal structures that negotiate with local governments. These organizations often secure limited formal benefits (IDs, uniforms, small wages/fees) for members. They collect user-fees directly (e.g. ₹85/mo per home) and supplement income by selling recyclables. SWaCH waste pickers report earning around ₹16,000 monthly between fees and scrap sales, and they receive training on waste segregation, safety and legal rights.[36]

4.1.5 case study

Sunita is a member of the SWaCH waste-picker cooperative in Pune. She collected dry waste door-to-door for 8 years, and had a volatile income, no health coverage and significantly more sever health complications due to her work, and in high collections seasons (around festivals) she would need to have her children miss school to work with her in waste sorting. She eventually joined the SWaCH cooperative, which is integrated in Pune's Material Recovery Facility, and now works with an official ID that provides her legitimacy, she works only with PPE, is subsidised for her smartphone as it is necessary for her work, receives upskilling in waste segregation and sorting, and has health care and social security benefits as part of the job. Her income rose by 25% as she is paid to collect waste, and she also sorts and sells the waste she collects. Her health has improved and her children's educational outcomes are improving due to their uninterrupted schooling. At a city level, dry-waste recovery has improved significantly, and the Pune municipality has extended their contract with SWaCH. SWaCH has also diversified its services by collecting new kinds of waste, such as e-waste and old clothes, and providing value-added services, such as composting waste at the source.

4.1.6 case study: AMP / AMP-style AI + robotics sorting (industrial automation)

A critical problem in India's waste story is that contamination and mixed streams reduce MRF value. Waste must be sorted into its various components for their inclusion in a value chain. Currently, sorting is primarily done by hand, resulting in hazardous working conditions for waste pickers and their families.

However, advancements in AI and robotics have allowed for the establishment of fully automated facility-scale smart sortation solutions such as AMP ONE. These solutions use machine-learning vision and robotic pickers to identify and pick a wide range of materials at high speed, improving recovery and reducing manual hazardous sorting. They are currently operating in European, North American, and Japanese markets, but with an eye on adapting their technology and expanding to countries in the Global South. At their current model, a mid size facility would cost several crore, and is therefore primarily a product for public purchase or entrepreneurs at the higher end of the value chain.

However, if the model was to be adapted, it would raise recovery rates, reduce degradation of high value material, and increase workplace safety for waste pickers. To protect livelihoods for waste pickers and ensure their ability to move higher in the waste economy, bundling these sorting stations with worker cooperatives would allow for the integration of waste collection, waste sorting, waste upcycling, and improvement in waste worker rights, health, and income.

4.1.7 the^delta take and ecosystem implications

Municipal solid waste has become India's most visible urban climate and livelihood challenge. Cities generate 156,000–170,000 tonnes of MSW every day—over 60 Mt annually—yet less than 55% is treated and nearly a quarter remains openly dumped. Poor segregation at source (below 20%) undermines recovery and feeds methane-emitting landfills, where fires and floods release toxins that disproportionately impact low-income settlements. Informal workers—an estimated 1.5–4 million waste pickers, sweepers, and recyclers—drive much of the system but face extreme heat, unsafe exposure, and erratic incomes. Methane emissions from open dumps are now visible on satellite monitoring, marking them among India's largest urban greenhouse gas sources.

Technology is redefining what's possible. IoT-enabled smart bins and AI route-optimisation platforms are cutting emissions from diesel fleets and stabilising operations under climate stress. Robotic sorting lines, optical MRFs, and automated composting units improve material recovery while reducing worker exposure. Decentralised bio-CNG and compost hubs turn organics into energy and soil carbon, while digital worker ID systems and traceable payment apps integrate informal workers into formal circular economies. When paired with methane abatement through drone and satellite monitoring, these interventions can turn waste management from a high-cost municipal service into an investable, low-carbon livelihood system for urban India.

4.2 plastic waste

Plastic waste is India's most visible and politically charged waste challenge—and also its largest opportunity for inclusive circularity. It cuts across urban and rural demographics, offers immediate climate co-benefits through emission reduction, and is a proven livelihood generator for over a million informal waste workers. With regulatory pressure (EPR mandates) and corporate demand for recycled polymers increasing, this sector is ripe for scalable, tech-enabled investment.

4.2.1 scale of the problem

India generates around 9–10 Mt of post-consumer plastic waste per year. Major sources are packaging (films, pouches, sachets), single-use products, and PET/HDPE bottles. Low- and medium-value plastics—like multilayer packaging (MLP), LDPE, and PS—constitute nearly half of all discarded plastics and lack viable recycling infrastructure.[37]

Roughly 60–70% of plastic waste enters recovery channels (largely via the informal sector); the remainder is mismanaged (landfilled, burned, or leaked to the environment).[38] This recovery rate is high relative to many countries — but most recovered material is low-value or downcycled. Urban metros and coastal states account for a large share of volumes - coastal litter hotspots also concentrate leakage. Plastic leakage contributes to marine and river pollution (economic losses to fisheries and tourism) and increases costs for municipal drainage and flood management.

Packaging waste is ubiquitous across city and rural consumer markets. Plastics are light by weight but high in volume and value; mismanagement causes local flooding (blocked drains), microplastic pollution of soils and rivers, lost feedstock for industry, and significant climate impact when virgin polymer manufacture is substituted by recycled resin. Rough estimates in the compiled research show tens of thousands of crores of rupees of lost material value annually when plastics leak or are downcycled instead of recovered into higher-value feedstock. Substituting recycled resin for virgin plastic saves roughly 1.5–3 tCO_2e per tonne depending on polymer and process; scaling recycled content therefore delivers measurable emissions reductions.

An estimated ₹20,000 crore of recoverable plastic value is lost annually due to poor segregation and market failure for low-value plastics.[39] Tackling this by expanding mechanical and chemical recycling could reduce virgin plastic demand by 25% by 2040.

> **If India's unrecycled plastic was to be burned for fuel, the CO2 released could power 1.5 million homes for a year.**

4.2.2 the human cost

Informal collectors and aggregators ("kabadiwalas", waste-pickers) form the backbone of plastic recovery—about 1.5–4 million informal waste pickers collect, sort, and trade recyclables. Most earn ₹100–₹400 per day with no formal recognition or safety net. Women constitute nearly 60% of this workforce. Vulnerable communities near dumps and small processing yards are exposed to dust, burning emissions and microplastic contamination; informal workers lack PPE, insurance and secure income. Formal recyclers rely on these supply chains to source feedstock, but compensation isn't proportional to their effort, or the value they provide to climatic conditions, or the benefits that populations incur from the convenience of waste pickers in urban spaces.

chemical depolymerisation

Multilayer packaging (MLP)—packets and sachets composed of mixed polymers—has long resisted conventional mechanical recycling due to its heterogeneous composition. European firms are experimenting with chemical depolymerisation where these plastics are broken down into monomers, allowing re-manufacture of food-grade packaging materials.

Depolymerisation uses thermal, catalytic, or enzymatic reactions to split polymer chains into constituent monomers such as ethylene, propylene, or terephthalic acid. When purified, these can be fed directly into existing polymerisation lines, producing recycled resin indistinguishable from virgin-grade plastic. The most successful European examples (e.g., Carbios in France, and Repsol and Plastic Energy plants in Spain and the Netherlands) integrate depolymerisation within industrial parks, sharing energy streams and logistics infrastructure to improve efficiency.

CARBIOS - converting low value waste to high value plastic

CARBIOS, a French biotechnology company, converts mixed and contaminated plastic waste into high-purity monomers. These are then re-polymerised into food-grade recycled PET (rPET), closing the loop on materials that mechanical recycling cannot process. In collaboration with MRF cooperatives in France, CARBIOS has secured feedstock and can now churn out recycled high value resin at scale.

4.2.2 the^delta take and ecosystem implications

Plastic waste now defines the frontier of India's urban circularity and climate challenge. The country produces between 4–9 Mt of plastic waste annually, yet recycling rates remain uneven—ranging from ~13% to 60% depending on region and resin type. Roughly 40% of plastics remain uncollected or mismanaged, leaking into land, rivers, and coastal ecosystems. In cities, the informal recycling economy supports nearly 1.5–2 million livelihoods, yet workers face hazardous exposure to fumes and floods, while multilayered plastics and low-value films—over half the total waste stream—remain economically unrecyclable. Microplastics now contaminate soil and groundwater, and open burning contributes to urban air pollution and carbon emissions.

The transition opportunity is clear. AI- and sensor-based sorting systems, digital watermarking (HolyGrail 2.0), and robotic material recovery facilities are raising purity rates for recyclables. Chemical and enzymatic recycling innovations—like PET depolymerisation (Carbios) and supercritical pyrolysis—are enabling recovery from hard-to-recycle plastics. Blockchain-linked EPR tracking platforms, mobile apps connecting informal pickers to recyclers, and low-cost densifiers for small entrepreneurs are formalising the value chain. If scaled with policy coherence and green finance, these technologies can transform plastic waste from an environmental burden into a traceable, low-carbon industry supporting dignified urban livelihoods.

4.3 textile waste

Textile waste embodies both India's industrial strength and its sustainability gap. As one of the world's largest textile producers, India's shift to circular manufacturing can attract ESG-aligned capital, revive traditional clusters, and unlock export competitiveness under global green trade norms.

India generates several Mt of textile waste annually — estimates at about 8 Mt a year of pre and post consumer textile waste which in turn is about 8.5 % of the global total.[40] Pre-consumer waste (cutting scraps) is concentrated in manufacturing hubs (Tirupur, Surat, Coimbatore) while post-consumer waste accumulates in urban centres.

Recycling cotton from textile waste would conserve thousands of cubic metres of water, reduce CO2 emissions, preserve energy and fiber. To be noted though, the economics of pre-consumer collection are easier than post-consumer because quality is higher. Blended-fiber garments (poly-cotton) increase recycling complexity. Only 1% of post-consumer waste re-enters textile-to-textile recycling; 41% ends up in landfills or is incinerated.[41] Large volumes therefore end in landfills or are burned causing microplastic leakage and air pollution. In the current system, ₹25,000–30,000 crore in recoverable fabric value is lost annually due to downcycling.[42]

only 1 %
is recycled

41 %
ends up landfilled or burned

4.3.1 the human cost

- Over 4 million informal and semi-formal workers engage in collection, sorting, and mechanical recycling across Panipat, Tirupur, Ludhiana, Surat, Coimbatore[43]
- Rag-pickers, garment-sector informal workers, and women in sorting units (often low paid) handle large portions of textiles destined for downcycling or disposal. Many are women from marginalised backgrounds
- Health impacts include dust exposure and chemical residue from dyes

4.3.2 viable technologies

The textile sector currently does not have any frameworks for either waste management rules, or extended producer responsibility. Efforts in this space will be primarily market driven, by Indian industry. Early movers in this space include Birla Cellulose — part of the Aditya Birla Group — who have inked several partnerships and innovations to drive circularity in the textile sector. One major initiative is its 2024 strategic alliance with Circ (US), under which Birla Cellulose has committed to purchasing up to 5,000 tonnes of Circ's recycled pulp each year over a five-year period; this pulp will be converted into lyocell staple fibre, enabling recycled feed-stocks to enter global fibre supply chains. Through its internal "Next Gen Solutions" programme (including its "Liva Reviva" line) Birla Cellulose has developed fibres made using pre-consumer textile waste feed-stock (≈ 20 %) and recycled cotton waste, blending them into its viscose/modals to shift from linear to circular business models.

4.3.3 home grown, labour forward initiatives

ReCircle is a Mumbai-based social enterprise pioneering a traceable, inclusive circular model for textile waste management in India. Operating through its Textile Recovery Facilities (TRFs), the company aggregates post-consumer and post-industrial textiles from households, corporates, schools, and factories, using a network of over 3,000 waste workers and collection partners across 270+ cities. The collected waste is sorted, graded, and channelled into recycling, upcycling, or repurposing streams, ensuring maximum material recovery and minimal landfill diversion. A defining feature of ReCircle's model is digital traceability—every kilogram of waste is tracked via its proprietary TRACE platform, enabling brands to verify sustainability metrics and extended producer responsibility (EPR) compliance. By combining grassroots collection infrastructure, data transparency, and industry partnerships (with players such as Birla Cellulose and Reliance Industries), ReCircle demonstrates how India can localise global circularity ambitions.

4.4 the^delta take and ecosystem implications

Textile waste now sits at the confluence of India's manufacturing strength, consumption surge and rural-urban livelihood challenge. India generates roughly 7.7–7.8 Mt of textile waste annually, which accounts for about 8.5% of the global total. Of this, over half comes from post-consumer streams (~51%), with ~42% from pre-consumer fabric/off-cut waste, and ~7% imported waste. Much of it ends up in landfills or down-cycled at low value, while the informal workforce of sorters, rag-pickers and small recyclers remains unpaid, informal and exposed to heat, dust, and fibre-aggregate hazards.

The mechanisms of challenge include slow uptake of textile-to-textile recycling, mixed-fibre complexity, limited collection infrastructure, low demand for recycled contents, and weak integration of workers into value chains.

Livelihood and productivity implications are stark: manufacturers lose potential feed-stocks; waste actors lack stable income or protections; and communities face micro-fibre pollution, landfill overflow and climate-linked heat exposure in sorting yards.

Technology-led pathways offer promise: high-precision AI-driven garment sorting and fibre-identification, chemical/enzymatic recycling of blended fabrics, modular shredding and fibre-re-spinning plants, and digital platforms for traceability and worker registration can bridge value-chain gaps.

In the the^delta voice: By treating textile waste as a raw material asset rather than a disposal burden, India can unlock circular livelihoods, reduce landfill emissions and position its textile industry for global competitive strength.

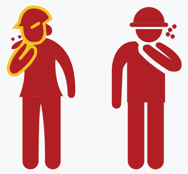
4.5 construction & demolition (C&D) waste

Construction and demolition waste is one of the top 3 contributors to India's greenhouse gas emissions. Large metros generate thousands of tonnes/day, with some estimates predicting 750 million metric tonnes annually. In sheer volume, C&D waste is significantly larger than MSW due to the dense nature of concrete, brick and soil. National totals are massive relative to the currently installed and established recycling capacity (<10–15% formal processing in many cities).[44] Untreated C&D waste means lost aggregates of sand and gravel which then drives unsustainable sand mining; and the corresponding embodied carbon from new concrete production remains high. Unused aggregates represent tens of billions of rupees in lost material value annually at scale.

4.5.1 the human cost

Disposing of construction and demolition waste causes significant health risks to those in the waste supply chain. Demolition crews are often migrant laborers who have no access to protective equipment, and the waste is passed on to small contractors and informal recyclers who are responsible for manual breaking and dismantling of the waste, some of which is toxic. Dust inhalation, especially silica dust released during cutting or breaking concrete, causes silicosis, chronic obstructive pulmonary disease (COPD), and lung cancer over time. Asbestos fibres, still found in older demolition materials, lead to asbestosis and mesothelioma. Contact with cement, paints, solvents, and insulation materials can cause chemical burns, dermatitis. Prolonged exposure to heavy metals such as lead, mercury, and cadmium—common in paints and electronic debris mixed into construction waste—can result in neurological and kidney damage. Without gloves or boots, workers often suffer puncture wounds, infections, and musculoskeletal injuries from lifting heavy or irregular debris. The lack of proper masks, helmets, and ventilation also increases vulnerability to heat stress, noise-induced hearing loss, and respiratory infections.

This waste also follows labour home. Dust and chemicals from their clothes transfer to their families. Labour also live in communities near illegal dumps which face blocked drainage and dust pollution.[45]



Imagine a construction site where every second worker is in pain

5 in 10 construction workers suffer chronic pain, many more struggle with dust, eye irritation and skin rashes, yet they keep building India's cities without safety gear or protection.

If you lined up 10 construction workers in India, 5 would be struggling with chronic back or joint pain, and several more would be coughing, rubbing their eyes, or fighting skin rashes from constant exposure to dust and debris. It's as if half the team building our cities can't lift, bend, or breathe properly — yet they keep working because they have no safety gear, no protection, and no choice.

However, utilising C&D waste is a materials security play. Recycling concrete, brick, and asphalt into certified aggregates lowers project costs and emissions, while creating semi-skilled jobs in sorting, crushing, and logistics. With India's infrastructure boom, demand for recycled aggregates is durable and policy-supported.[46]

4.5.2 best practices

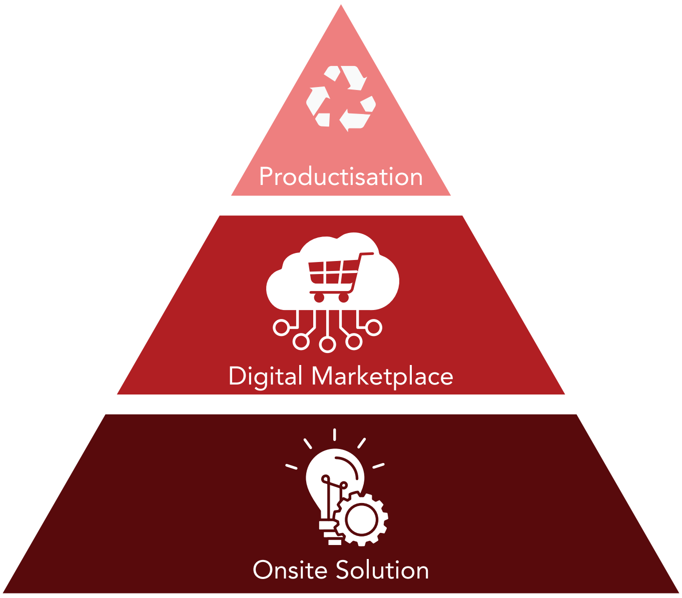
Beginning in 2025, the UK is implementing a mandatory digital waste-tracking service that will create a comprehensive, end-to-end electronic chain of custody for waste streams — from the point of generation (such as construction or demolition sites) through transport, processing, reuse, or disposal. This system is designed to replace manual waste-transfer notes with digital manifests, enabling real-time visibility and data-integration across industry stakeholders and regulators. As a benchmark for global best practice, it aims to enhance accountability (reducing illegal dumping and fly-tipping), improve material-flow transparency (key for circular-economy metrics), support compliance with extended producer responsibility frameworks, and build market trust in recycled materials by validating their origin and processing history.

Construction isn't a boutique industry, and requires extensive solutions for the waste problem. At the individual level, protective equipment is an immediate step but that is primarily driven by contractors and project site managers, as opposed to the market. The market play in construction will have to happen at an industry level:

- On-site mobile crushers and sorting yards for contractors, plus fixed recycling yards near urban clusters
- Digital marketplaces that match demolition projects to recyclers help secure feedstock
- Productisation: recycled aggregate blocks, paving slabs, and structural fill for roads

tracking waste, transforming construction

Industry-level solutions
for construction waste



Market-driven circularity begins with
industrial coordination not individual effort

4.5.3 the^delta take and ecosystem implications

Construction and demolition (C&D) waste has become one of India's largest and most undervalued urban material streams, deeply tied to the country's infrastructure growth and environmental stress. India generates an estimated 150–500 Mt of C&D waste annually, yet less than 1% is formally recycled. The rest—comprising concrete, steel, sand, bricks, and debris—is often dumped in low-lying areas or along roadsides, worsening urban flooding, air pollution, and land degradation. Informal labourers, small contractors, and migrant demolition workers operate in unsafe, unregulated conditions, exposed to dust, heavy metals, and heat stress, with limited income stability or safety gear. The sector's inefficiencies also carry economic costs: cities lose potential aggregate value and spend heavily on debris clearance and landfill maintenance.

Technological interventions now make large-scale circularity feasible. Automated crushing and sorting plants, on-site mini-recycling units, and AI-based quality control can recover aggregates and sand substitutes with consistent standards. Digital marketplaces linking small contractors to recycled material buyers, along with drone and satellite monitoring to track illegal dumping, can improve compliance and transparency. Modular recycling clusters and verified carbon savings can attract green financing, turning C&D waste into a viable circular economy sector. When paired with worker formalisation and protective equipment, India's rubble problem could evolve into a resource opportunity—reducing emissions, creating safer livelihoods, and supporting sustainable urban growth.

4.6 e-waste

E-waste is India's fastest-growing waste stream, directly tied to the country's digital economy. It offers both a high-value materials recovery opportunity - as metals like gold, copper, and lithium are embedded in waste electronics - and a pathway to safer, formal livelihoods for informal dismantlers if structured well. However, due to the primitive nature of waste segregation and dismantling in the sector, the human cost is immense currently, with children being a core demographic of concern.

4.6.1 what is being picked up

In the 2024-2025 financial year, 1.4 million metric tonnes of e-waste was generated in India, which was roughly double 2017–18 levels of 0.7 million metric tonnes.[47] 95 % is handled informally, and only 40% enters formal recycling systems.[48] The 2024–25 e-waste tonnage contains substantial recoverable metals: estimates show 320 tonnes of gold, 2,400 tonnes silver, and 40,000 tonnes of copper - values that largely leak when processed informally. India loses an estimated ₹529 billion annually in unrecovered precious and base metals.[49] This represents hundreds of crore of lost recoverable resource value if not recovered formally.

4.6.2 who picks up our old cellphones

Organically developed e-waste recycling hubs and informal material recovery facilities rely on networks of informal collectors, dismantlers, and small-scale recyclers who handle the initial stages of e-waste processing. Roughly 300,000–500,000 informal workers dismantle and trade e-waste.[50] Their deep local knowledge and community involvement enable them to manage significant volumes of e-waste adeptly despite the lack of formal infrastructure.[51] Income is generated from low-margin resale of recovered components. In these hubs, informal dismantlers, kabadiwalas and small refurbishers (many migrants, including children in areas with high volume) perform manual disassembly and acid/heat processing without PPE, exposing families and neighbours to lead, mercury, brominated flame retardants and other toxics. Health impacts are documented near dismantling clusters: soil/water contamination and elevated blood lead levels among children.

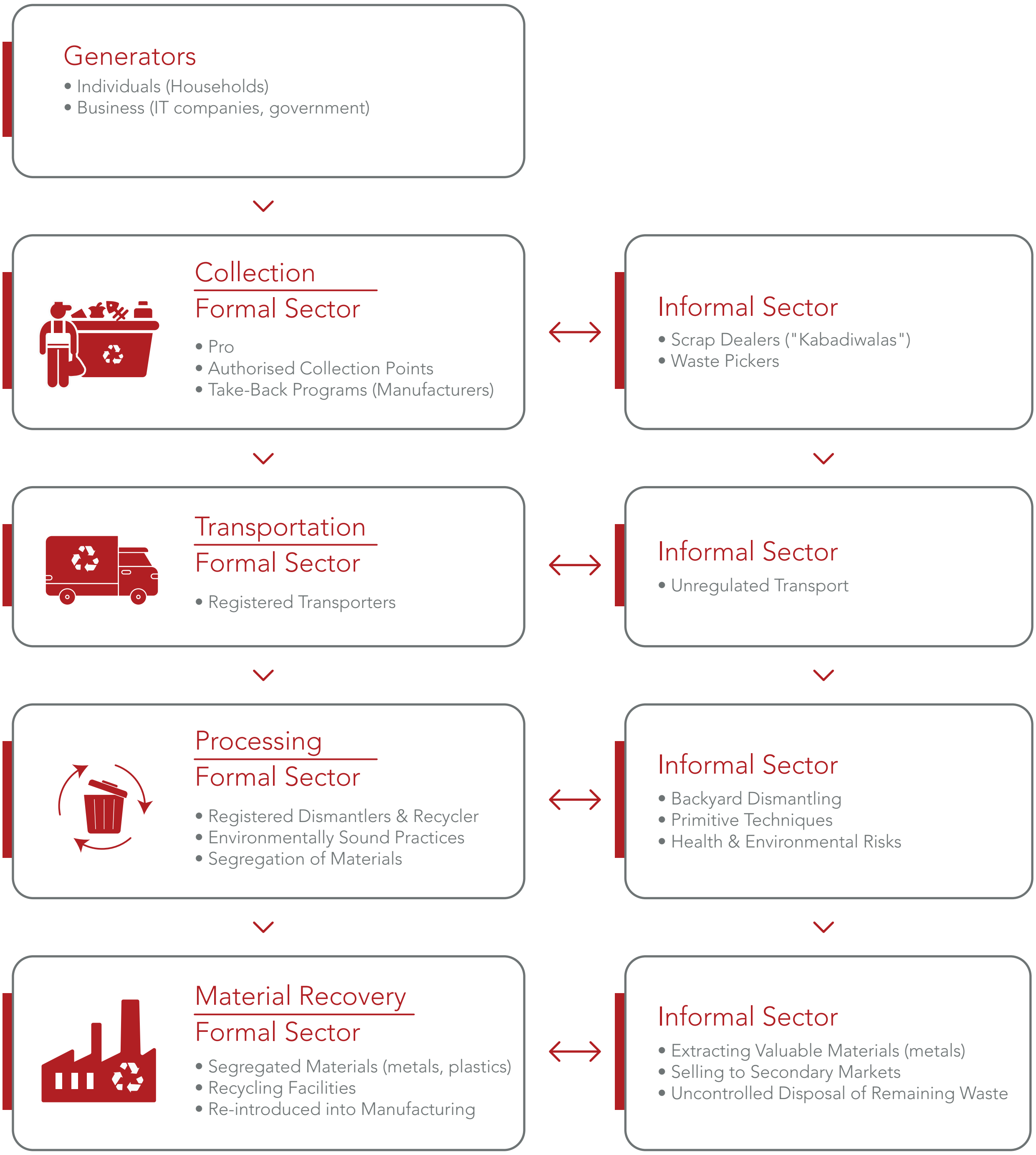


Table: E-waste processing chain[52]

4.6.3 policy and market readiness

Technological advancements such as mechanised shredders, robotics and modular mobile units are slowly becoming available, but these all require scaled formal collection and feedstock consistency. India's E-Waste (Management) Rules, 2016 (updated 2022) requires formalisation and Extended Producer Responsibility, and the CPCB registers dismantlers/recyclers. Currently, more than 470 recyclers have been registered with the CPCB[53] and efforts are underway to provide targets for recyclers to meet collection needs. Recycling targets will promote secure markets for informal collectors, albeit this is pending an implementation push from the government.

redwood materials: closing the loop on battery metals

Redwood Materials, founded in the United States, has established itself as a global leader in battery material recovery and circular manufacturing. The company uses a hybrid process combining mechanical shredding and hydrometallurgy to extract more than 90% of critical metals—lithium, nickel, cobalt, and copper—from end-of-life batteries and production scrap. Before recycling, usable batteries are repurposed for stationary energy storage, extending their lifecycle and maximising value recovery. Redwood's industrial-scale facilities demonstrate that battery recycling can operate safely and profitably when technology, logistics, and partnerships are aligned. The recovered materials are reintroduced into battery production lines, effectively closing the loop between manufacturing and recycling while lowering emissions and reducing reliance on newly mined resources.

4.6.4 the rare earth mandate

E-waste recycling is not just a clean-up mission; it could be India's gateway to rare earth independence — where every discarded device becomes a deposit for the industries of the future.

Rare earth elements (REEs) like neodymium, dysprosium, and terbium power the backbone of modern technology — from EV motors and wind turbines to smartphones and defence electronics. Yet, over 90% of the world's REE supply is mined and refined in China, creating global dependence and environmental costs. As India's electronics, renewable, and mobility sectors accelerate, the country's e-waste stream has become an untapped source of strategic minerals.

E-waste from phones, appliances, and EV batteries contains valuable traces of critical and rare earth metals embedded in magnets, displays, and circuit boards. Through advanced mechanical, hydrometallurgical, and magnetic recovery processes, these materials can be extracted and reintroduced into manufacturing — turning discarded devices into domestic mineral reserves. Urban mining could offset a significant share of India's demand for imported REEs while creating high-value recycling and refining jobs.

India's E-Waste (Management) Rules, 2022 already embed Extended Producer Responsibility (EPR) for formal collection and recycling. The emerging National Critical Minerals Strategy (2025) by the Ministry of Mines, identifies rare earths as vital to energy security, signalling a shift from waste regulation to resource strategy. Integrating REE recovery targets within EPR frameworks, and supporting urban mining hubs in major cities, can bridge these agendas — advancing both strategic autonomy and circular manufacturing.

4.6.5 the^delta take and ecosystem implications

Electronic waste now sits at the centre of India's urban circularity and livelihood challenge. The country generated 1.1 Mt of e-waste in 2023—ranking third globally after China and the United States—yet over 85–95% is still dismantled or recycled informally through unsafe burning and acid leaching. Only ~22% of global e-waste is officially collected, and valuable materials such as gold, copper, cobalt, and rare earths worth billions remain unrecovered each year. In India's urban clusters, informal e-waste work sustains hundreds of thousands of livelihoods but exposes workers—often women and children—to lead, mercury, and persistent heat stress. Batteries, PV panels, and EV components are adding new toxicity risks, while existing facilities lack the scale or technology to safely process them.

The opportunity lies in building a connected, technology-enabled recovery ecosystem. AI-guided dismantling systems, robotic sorting arms, and machine-vision quality grading are improving material recovery efficiency and worker safety. Hydrometallurgical and bioleaching processes can reclaim up to 95% of critical metals without high heat or emissions. Digital EPR traceability platforms, worker ID systems, and mobile collection kiosks can formalise the informal sector, while blockchain-linked compliance credits can attract private finance to verified recovery chains. If harnessed systematically, e-waste can move from toxic leakage to a high-value urban mining industry—creating safer, data-traceable livelihoods while supplying metals essential for India's clean energy transition.

4.7 hazardous & industrial waste

India's industrial hazardous waste totals are in the millions of tonnes annually - 8 Metric tonnes industrial hazardous waste per year as a country-level estimate - excluding biomedical. Biomedical waste from healthcare separately accounts for 0.27 Metric tonnes/yr in recent figures. Main hazardous streams include but are not limited to solvent sludges, heavy-metal sludges, spent catalysts, used oils, chemical residues.

As a sector, hazardous waste has very high costs both environmentally and economically, with little potential for recycling and upcycling waste. Primary economic losses come from regulatory penalties, and loss of efficiency in factories[54] but market players here are more likely to focus on changing regulations as opposed to coming up with market innovations to reduce harm and increase efficiency. For instance, the Hazardous Waste (Management) Rules (2016, amended 2023) require tracking and authorised treatment. Smaller enterprises primarily use informal (and particularly hazardous) means for disposal. Remedial efforts require heavy capital expenditure, and don't generate return on the investment in a short term, either economically or environmentally. This means the human cost, borne by contracted sanitations workers and communities living near industrial clusters,[55] is not one easily resolved by market based inducement challenges.

4.8 the^delta take and ecosystem implications

Construction & demolition waste, hazardous and industrial waste, and e-waste represent India's most under-managed yet high-value urban waste streams. Together, they account for millions of tonnes of recoverable material annually—concrete, metals, chemicals, and electronics—yet less than 20% is formally recycled. C&D waste, generated at unprecedented pace by urban expansion, is largely dumped in open areas or drains, worsening flooding and air pollution. Workers—often migrants—handle debris without safety gear in extreme heat, facing dust-related illnesses and frequent injuries. Industrial and hazardous wastes from small factories, tanneries, and dyeing units leak into air and water, especially during floods, exposing workers and nearby low-income settlements to toxic contamination. Meanwhile, over 90% of India's e-waste is processed informally through burning or acid leaching, releasing heavy metals and fumes that endanger informal recyclers, including women and children.

A technology-first shift can unlock both safety and value. Affordable mobile crushers and automated sorting units can decentralise C&D recycling; digital traceability and online marketplaces can link small contractors to secondary material buyers; wearable protective equipment and safe dismantling kits can reduce exposure in e-waste and industrial recovery; and digital compliance platforms can help formalise recyclers and connect them to extended producer responsibility (EPR) systems. With verified data, AI-enabled tracking, and inclusive finance, these waste streams can evolve from pollution risks into scalable, circular industries that generate safer, higher-value livelihoods across India's industrial and urban frontiers. However, prioritising mitigation of their climatic impact would be critical moving forward.

5
an ecosystem of waste management

Incentive based challenges to infuse competition and innovation into markets work best when an entire ecosystem enables invention, innovation, and implementation. Policy and regulatory systems create the scope conditions within which innovation can happen, while financial systems enable scale and rapid adoption.

5.1 policy landscape

Key legal drivers in the space of waste in India include but are not limited to:

- SWM Rules (2016, amendments 2022)
- Plastic Waste Management Rules (EPR)
- E-Waste Rules (2016, updated 2022)
- Hazardous Waste Rules (2016, amended 2023)
- Battery Waste Rules (2022)
- Construction & Demolition Waste Management Rules (2016, amended 2023)
- Swachh Bharat Mission 2.0 (MoHUA)
- SATAT (Sustainable Alternative Towards Affordable Transportation)
- Circular Economy Roadmap (NITI Aayog, 2023)

These create obligations that open producer-funded markets (EPR), while sanitation and Swachh Bharat funding provides municipal capital. However enforcement and consistent state-level implementation are uneven; this is both a policy risk and an opportunity for early movers to partner with better-performing ULBs.

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The government is also currently putting its money where its mouth is:

- SIDBI Green MSME Platform — supports recycling MSMEs via concessional loans and tech upgradation grants
- NABARD Bioenergy Fund — finances village-scale biogas and briquette enterprises through FPOs
- Startup India – Waste Tech Vertical (DPIIT) — early-stage innovation support for traceability, robotics, and AI-led waste mapping
- State Circular Economy Missions (Maharashtra, Karnataka, Tamil Nadu) — incentives for recycled-content manufacturing and waste park development

5.2 private financing

Blended finance (grant + concessional debt + commercial equity) works well for early-stage clusters (e.g. bio-CNG, MRFs, textile pilot plants). EPR contracts provide predictable revenue streams where producers pay collectors/processors thus ensuring a market. Franchise/co-op models (buy-back kiosks, MRF cooperatives) are low investment ways to formalise livelihoods and secure feedstock.

Green finance funds such as Circulate Capital, Aavishkaar Capital, Blue Earth Capital, National Investment and Infrastructure Fund Ltd (NIIF), and responsAbility Investments AG are working with the waste economy across the innovation ecosystem - including early stage, infrastructure, and international - and have a foothold in the India ecosystem.

5.3 investing in India's circular waste economy

India's waste sector stands at the convergence of three major transitions:

- Economic — moving from an informal, low-value system to a structured, investable circular market;
- Technological — adopting digital and science-first approaches to waste identification, sorting, and processing;
- Social — embedding livelihood and dignity at the core of climate solutions.

If waste was India's 20th-century liability, it can become its 21st-century advantage.

Circularity in waste is not just a sustainability agenda—it could be the next major livelihood and technology frontier. By 2035, India's waste economy could anchor 10 million green jobs, reduce annual GHG emissions by 200 Mt CO_2e, and generate USD 20–25 billion in circular market value.[56]

The time to invest is now.

Annexure

works cited

- CPCB. Annual Report on Solid Waste Management Rules 2022–23. (2024)
- MoEFCC. E-Waste & Plastic Waste Management Rules 2022–23.
- TERI. Circular Economy in India's Waste Sector. (2024)
- NITI Aayog. Waste-to-Wealth Mission Progress Report. (2024)
- World Bank. What a Waste 2.0 – South Asia Update. (2023)
- ICMR. Health Impacts of Poor Waste Management in India. (2023)
- Fashion for Good. India Textile Recycling Landscape. (2023)
- Confederation of Indian Industry (CII). Plastics and Electronics Circularity in India. (2024)
- FAO India. Reducing Post-Harvest Food Loss. (2023)
- MoHUA. Swachh Bharat Mission 2.0 Annual Report. (2023)
- Amrita Goldar, Kartik Nair, Md Sarwar Ali and Ritika Verma. Unravelling India's E-Waste Supply Chain: A Comprehensive Analysis and Mapping of the Key Actors Involved. ICRIER (2024)
- CEEW, 2023
- MoT, 2023
- UNEP/ILO, 2022–23
- Fortune India, 2024)
- FAO, 2024
- MNRE/MoPNG SATAT, 2023–24
- BIS, 2022
- IPCC, 2022: Summary for Policymakers. Climate Change 2022: Impacts, Adaptation, and Vulnerability. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3-33.
- Verner, M., Marlon, et al. (2025). Climate Impacts in India: Experience, Worry, and Attribution to Global Warming. Yale University. New Haven, CT: Yale Program on Climate Change Communication.
- Prabhu, Shravan, et al. 2025. How Extreme Heat is Impacting India: Assessing District-level Heat Risk. New Delhi: Council on Energy, Environment and Water.
- Climate Investment Opportunities in India's Cooling Sector. (2022). International Bank for Reconstruction and Development / The World Bank.
- SELCO Foundation. (2023) SELCAP: Sustainable Energy Led Climate Action Program.
- Anand, Channi et al. (2024). For India's garbage pickers, a miserable and dangerous job made worse by extreme heat. AP News.
- Gawade, Shatakshi (2025). Empowering waste pickers with dignified jobs for environmental change. Mongabay.
- In over 90% of sewer deaths, workers had no safety gear: government audit. The Hindu.
- Here's your Works Cited section rewritten to match the format you specified (author, year, title, publisher/source):
- Carbios. (2024). Carbios begins construction of the world's first PET biorecycling plant. Carbios Newsroom.
- Central Pollution Control Board (CPCB). (2023). Annual report on plastic waste management for FY 2022–23. Ministry of Environment, Forest and Climate Change, Government of India.
- Ellen MacArthur Foundation. (2023). Global commitment progress report 2023. Ellen MacArthur Foundation.
- Central Pollution Control Board (CPCB). (2023). Annual report on plastic waste management for FY 2022–23. Ministry of Environment, Forest and Climate Change, Government of India.
- Ellen MacArthur Foundation. (2023). Global commitment progress report 2023. Ellen MacArthur Foundation.
- European Brands Association (AIM). (2023). HolyGrail 2.0: Digital watermarks initiative for circular economy – Pilot results. AIM.
- International Solid Waste Association (ISWA). (2022). Global review of plastic waste management practices. ISWA.
- Revalyu Resources. (2024). Chemical recycling of PET bottles: Facility overview. Revalyu.
- Systemiq & The Minderoo Foundation. (2023). The Plastic Waste Makers Index 2023. Minderoo Foundation.
- United Nations Environment Programme (UNEP). (2024). Turning off the tap: How the world can end plastic pollution and create a circular economy. United Nations Environment Programme.

- Central Pollution Control Board (CPCB). (2024). Annual Report 2021–22 on implementation of Solid Waste Management Rules. CPCB.
- Central Pollution Control Board (CPCB). (2024). Annual Report 2020–21 on implementation of Solid Waste Management Rules. CPCB.
- Council on Energy, Environment and Water (CEEW). (2025). How can Indian cities boost sustainable solid waste management practices. CEEW.
- Kannankai, M. P. et al. (2024). Air quality impacts of landfill fires: A case study from the Brahmapuram MSW plant, Kochi. Science of the Total Environment (Elsevier).
- Times of India Staff. (2024). Brahmapuram landfill fires: Impact on greenhouse gas emissions and public health. The Times of India.
- British Safety Council India. (2025). India's waste pickers: Indispensable but invisible. Safety Management.
- GHGSat. (2025). The role of satellite data in landfill methane management. GHGSat Newsroom.
- GHGSat. (2025). Methane Emissions Report 2024. GHGSat.
- MoSPI. (2023). EnviStats India, Vol. II: Environment accounts—Waste and emissions. Ministry of Statistics and Programme Implementation, Government of India.
- CPCB. (n.d.). National Action Plan for Municipal Solid Waste. Central Pollution Control Board.
- International Telecommunication Union (ITU) & United Nations Institute for Training and Research (UNITAR). (2024). The Global E-waste Monitor 2024. ITU/UNITAR.
- Central Pollution Control Board (CPCB). (2023). Annual report on E-Waste (Management) Rules, 2022. Ministry of Environment, Forest and Climate Change, Government of India.
- Press Information Bureau, Government of India (PIB). (2023). India's formal e-waste collection doubles under EPR regime. PIB.
- World Health Organization (WHO). (2024). Electronic waste (e-waste): Key health impacts and vulnerable groups. WHO.
- Times of India Staff. (2025). 95% of Delhi's e-junk still handled informally. The Times of India.
- Down To Earth Staff. (2024). How e-waste recycling remains an informal and hazardous business. Down To Earth.
- Sandwal, S. K., & colleagues. (2025). E-waste challenges in India: Environmental and human health risks. Applied Sciences (MDPI).
- Reuters Staff. (2025). LG, Samsung challenge new e-waste pricing policy in India. Reuters.
- Fashion for Good. (n.d.). Wealth in Waste: India's potential to lead circular textile sourcing. Fashion for Good. Fashion for Good
- IndiaSpend. (2024, Nov 23). Textile waste a growing environmental concern. IndiaSpend. Indiaspend
- Enviu. (2025). Issues to Action: Exploring India's textile waste landscape. Enviu. Enviu
- Enviu. (2025). Issues to Action: Exploring India's textile waste landscape. Enviu. Enviu
- Centre for Science and Environment (CSE). (2020, August 25). India recycles only 1% of its construction and demolition waste. Down To Earth.
- Council on Energy, Environment and Water (CEEW). (2023). Construction and demolition waste recycling. CEEW.
- ResearchGate. (2022). Challenges and prospects of demolition waste recycling in India. ResearchGate.
- Urban Infra Group. (2024, May). From rubble to riches: Unlocking the hidden value of construction waste in India. Urban Infra Group.

endnotes

1. Verner, M., Marlon, et al. (2025).
2. On extinctions of plant and animal species (61%), severe heat waves (56%), agricultural pests and diseases (62%), droughts and water shortages (58%), water pollution (55%), severe air pollution (54%), and famines and food shortages (51%).
3. Prabhu, Shravan, et al. 2025.
4. Climate Investment Opportunities in India's Cooling Sector. (2022).
5. SELCO Foundation. (2023)
6. World Bank 2023; MoHUA 2024
7. MoHUA 2023
8. AIWPA 2023
9. CII 2022
10. NITI Aayog 2023
11. Safai Karmacharis Commission, 2022
12. The Hindu.
13. UN-Habitat, 2023

14. CII 2022
15. CPCB 2022
16. MoEFCC 2023
17. NITI Aayog projections
18. MoA&FW, 2024; TERI, 2023; MoA&FW, 2023; FAO, 2024
19. MoA&FW, 2024
20. CPCB, 2023
21. Nature Comm., 2022
22. MNRE, 2023
23. ICAR, 2023
24. NABARD, 2023
25. IIT Delhi, 2022
26. ICMR, 2023
27. ICAR, 2023
28. MNRE, 2024
29. World Bank, 2023
28. MNRE, 2024
29. World Bank, 2023
30. MNRE, 2023; MoP, 2024
31. Anand, Channi et al. (2024).
32. ICMR, 2023
33. MoHUA, 2023
34. CII, 2022
35. UNEP, 2023
36. Gawade, Shatakshi (2025).
37. TERI, 2021
38. CPCB, 2024; MoEFCC, 2023
39. (World Bank, 2023)
40. ReWeave India, 2024
41. MoT, 2023
42. CEEW, 2024
43. ILO, 2022
44. MoHUA, 2023; CPCB, 2024
45. ILO, 2022
46. MoHUA, 2023; BIS, 2022
47. CPCB, 2024
48. UNEP, 2023
49. Fortune India, 2024
50. ILO, 2022
51. ICRIER, 2024
52. ICRIER 2024
53. MoEFCC, 2024
54. World Bank, 2023
55. ILO, 2022; CPCB, 2024
56. NITI Aayog, 2024; World Bank, 2023

This report is part of the Climate & Food Systems distillation study, powered by Spectrum Impact, the^delta prize and The/Nudge Institute. It will be followed by a roadmap study in partnership with MicroSave Consulting (MSC), highlighting key opportunity areas for market-driven, tech-enabled innovations.

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